PB-217 051

THE TEZUKA REFUSE COMPRESSION SYSTEM

Comsumer Protection and Environmental Health Service
Washington, D. C.

1969

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THE TEZUKA REFUSE COMPRESSION SYSTEM

A Preliminary Report

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
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Environmental Control Administration

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THE TEZUKA REFUSE COMPRESSION SYSTEM

A Preliminary Report

American Public Works Association Research Foundation
Chicago, Illinois, under Demonstration Project D01-UI-00073

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Consumer Protection and Environmental Health Service
Environmental Control Administration
Bureau of Solid Waste Management

1969

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FOREWORD

An estimated 800 million pounds of solid wastes of all types are produced in the United States every day. What to do with these solid wastes, how to dispose of them without needlessly endangering public health and welfare, and how to recover and reuse valuable materials now "thrown away" are among the most challenging and perplexing of current national problems. Because of lack of suitable planning, interest, and public understanding, these problems have reached such proportions that nationwide attention is demanded and action for the development of adequate solutions must be taken.

Intensified action concerning these problems was made possible by the Solid Waste Disposal Act, Title II of Public Law 89-272, signed by the President on October 20, 1965. This legislation directs the Secretary of the Department of Health, Education, and Welfare to initiate, encourage, and support a national program aimed at discovering and evaluating better methods of coping with the solid waste problem.

The Secretary is authorized: (1) to conduct and support research on the nature and scope of the problem, on methods of more safely and efficiently collecting and disposing of solid wastes, and on techniques for recovering from solid wastes potentially valuable materials and energy; (2) to provide training and financial and technical assistance to local and State agencies so that they can survey their needs in the solid waste area and plan for the development and staffing of programs capable of meeting those needs now and in the years to come; (3) to encourage and support projects that may demonstrate new and improved methods of solid waste collection, handling, and disposal.

To carry out these responsibilities, the Bureau of Solid Waste Management has been established. Among the responsibilities with which the Bureau is charged is that of providing grant support for demonstrations relating to the development and application of new and improved methods of solid waste collection, storage, processing and ultimate disposal; and also for studies and investigations that may lead to a demonstration of improved disposal practices, or may provide solutions for regional or national solid waste disposal problems. Associated with this is the responsibility of collecting and making available by appropriate means the results of, and other information pertaining to, such federally supported demonstrations, studies and investigations.

Accordingly, this report has been reproduced by the Bureau of Solid Waste Management to disseminate as widely as possible information concerning the Tezuka Refuse Compression System. Considerable interest in the Tezuka System exists among public works officials in this country, however, firsthand information concerning it has been lacking.

The report was developed by American Public Works Association Research Foundation in connection with a project receiving demonstration grant support from the Bureau of Solid Waste Management. This project, in which the potential benefits of rail haul as a part of solid waste disposal systems is being investigated, is described in the abstract included in this publication.

--RICHARD D. VAUGHAN, *Director*

Bureau of Solid Waste Management

ABSTRACT OF STUDY AND INVESTIGATION GRANT NO. DOI-UI-00073

TITLE: Investigate the Potential Benefits of Rail Haul as an Integral Part of Waste Disposal Systems

GRANTEE: American Public Works Association
1313 East 60th Street
Chicago, Illinois 60637

PROJECT DIRECTOR: Dr. Karl W. Wolf, Research Associate
American Public Works Association Research Foundation
c/o Museum of Science and Industry
Room C-209
57th and South Shore Drive
Chicago, Illinois 60637

PROJECT STARTED: April 1, 1967 PROJECT ENDS: June 30, 1971

OBJECTIVES: To determine the feasibility of new method of solid waste disposal by making a comprehensive evaluation of the costs and benefits obtainable for the collection, transportation and disposal of solid wastes from urban areas by the use of rail-haul techniques.

PROCEDURES: The project is being conducted in three phases, each of which is expected to take approximately a year to complete. Phase One is concerned with the identification, development and setting up of the rail haul and related solid waste transport and disposal techniques. Phase Two will deal mainly with implementation of the rail haul waste disposal concept in cooperation with selected communities. Phase Three will consist of a comprehensive evaluation of the concept and techniques as demonstrated under actual operating conditions during Phase Two.

The project is being conducted by staff of the American Public Works Association, with contractual professional and consulting services of various types being obtained as needed.

V

*** PREFACE ***

This analysis of the Tezuka Kosan Refuse Compression Process was developed as part of the APWA waste-rail-haul study.

This study is financed by the Solid Waste Program of the U.S. Public Health Service, the Penn Central Railroad and communities such as Marin County, California; District of Columbia; Chicago and Park Forest, Illinois; the Sanitary District of Chicago, Illinois; Elkhart, Indiana; Boston, Massachusetts; Grand Rapids, Michigan; Hempstead and New York, New York; Cincinnati, Cleveland and Columbus, Ohio; Norfolk, Virginia; and Winnipeg, Canada.

This report is published separately because of the widespread interest the Tezuka system has found among American and Canadian public works officials. Findings of the APWA rail-haul study to date suggest that refuse compression is the key to advantageous waste-rail-haul operations. At the present time the Japanese Tezuka system is the only pilot refuse compression process developed to approximately production scale.

This report exemplifies the close working relationship between operating public works officials and APWA research people. Such a relationship has been a hallmark of all APWA research projects. In this case the study team asked for and received the most generous cooperation from the City of Chicago.

I trust this report will prove to be useful to the many people working in the solid waste disposal field.

Fred J. Benson

Fred J. Benson

April 15, 1968

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I. INTRODUCTION

The Tezuka Refuse Compression System was developed by the Tezuka Kosan Company, Ltd., 39-31 7-Chome, Oshima-Machi, Koto-Ku, Tokyo, Japan.

The Tezuka Company spent ten years of research on the development of the system. The total development cost including the building of models and prototypes are quoted at one billion yen. This is the equivalent of about $2.77 million calculated at the current official exchange rate.

The Tezuka Refuse Compression System has found widespread interest in the United States as well as throughout the world. This interest is due to (a) problems caused by the large and ever-increasing volume of the refuse to be disposed of, (b) the more stringent demands for environmental improvements, and (c) the rapidly rising cost of the available refuse disposal methods.

This report is based on various information inputs. Mainly, these inputs consist of an on-site inspection of a full-scale prototype system in the Tezuka plant, the observation of two prototype demonstrations, and the literature and data obtained from Tezuka during the on-site inspection.

It should be stressed that the two prototype demonstrations were not part of a systematic or operationally complete refuse compression test series. The time and cost involved in such an undertaking made it impossible for the authors to even consider the performance of meaningful tests at that time. Thus, this evaluation must rely to a great extent on the data as presented by the Tezuka Kosan Company.

Due probably to translation difficulties, the available Tezuka literature contains statements which often are not conducive

to a clear interpretation and sometimes even appears contradictory. Unfortunately a systematically documented set of data to support the statements was not available.

Furthermore, the few data given are generally presented without intercorrelating references. This makes it difficult and sometimes impossible to reconcile or substantiate all the inferences made by Tezuka Kosan. It must be mentioned in this context that the Tezuka system as currently presented is not a well defined production line system. The descriptions available to date indicate many significant existing or potential variations for both the equipment and the mode of operations.

As a result this report should be considered as only a guide to a further evaluation of an innovative concept in the field of refuse disposal. This report is primarily written for public works officials who might wish to evaluate, on a preliminary basis, the Tezuka system as an alternative disposal method. The scientist, the value engineer and the process designer most certainly will need data which at the present time are either not available or non-existent.

Finally, this report contains the metric dimensions and values as given by Tezuka Kosan as well as the corresponding British/American measurements which were calculated. This dual data presentation was selected to provide convenient points of reference for readers having the Tezuka literature on hand.

II. SUMMARY AND CONCLUSIONS

1. The Tezuka Kosan Company is to date the only company that actually has produced large bales of refuse.

2. The Tezuka Kosan Company spent ten years of research and about $2.77 million on the development of its refuse compression system. The expenditures include the building of a full-scale press system valued at about $1.7 million in sales price.

3. The Tezuka Refuse Compression System has found widespread interest in the United States as well as throughout the world.

4. The Tezuka Refuse Compression System consists basically of three major system building blocks:

   a) the preliminary compression system,
   b) the main compression system, and
   c) equipment to add additional cover material such as asphalt or cement to the bales previously compressed within an enclosure such as chicken wire mesh.

5. Currently, Tezuka proposes two kinds of preliminary compression systems:

   a) a two or one stroke pre-compression approach, and
   b) an installation which might employ up to two presses of which one operates with three horizontal strokes.

6. The two or one stroke pre-compression system has already been built. The pressures exerted on the refuse in this system amount to about 221 psi.

7. The second pre-compression system consists of a hydraulically operated "hopper for feeding" refuse and a separate pre-compression

device. The maximum pressure exerted in the hopper on the refuse is about 425 psi. Specifications for the separate pre-compression device are not available and this sytem has not yet been built.

8. The proposed main compression system consists of standard and optional system elements.

9. The standard system elements include

   a) the main press,
   b) a mobile compression chamber and the associated bale enclosure,
   c) a compression chamber moving device,
   d) a device for closing the bale enclosure on top of the compacted bale while it is still in the compression chamber, and
   e) a push-up device to remove the bale from the compression chamber.

10. The optional system elements include additional mobile main compression chambers, the associated moving devices and a separate bale enclosure forming device.

    The separate bale enclosure forming device consists of a separate press and a mold similar in dimensions to the main compression chamber.

11. If a separate bale enclosure forming device is not given, the bale enclosures are formed by the main press in the main compression chamber prior to the loading of the refuse.

12. The main press operates vertically.

13. The pressures exerted on the main ram currently are quoted to range from 1200 to 1600 metric tons. The pressure face dimensions range from about 63 x 63 to about 71 x 71 inches. The length of the stroke is about 118 inches in all cases.

14. This report is primarily based on information given or inferred for a 1300 metric tons of force system. Except for variations in the dimensions, the basic approach is similar in all cases.

15. The main ram and its pressure face are designed to perform four different compression operations successively. The pressure face is subdivided into three sections.

16. In the first step the full amount of the available force is applied to all three pressure face sections. A pressure of about 675 psi is exerted on the refuse.

17. In the second step a force of only 600 metric tons is applied to a cylinder about 18 inches in diameter and about 19 inches in length.

    The cylinder moves downward out of the center of the main pressure face. A pressure of about 5120 psi may be exerted on the refuse.

    The pressure face of the center cylinder is in area the equivalent of about one-sixteenth of the total pressure face area indicated for the first step.

18. In the third step twelve smaller cylinders-distributed over the total original pressure face- are pushed downward. They work either simultaneously or individually in a prearranged pattern.

    Each of the twelve cylinders is about 6.8 inches in diameter and about 19 inches in length.

    A total force of 1080 metric tons is applied to the twelve cylinders, 90 metric tons on each. Thus each cylinder can exert a pressure of about 5278 psi on the refuse.

    The total pressure face area of the twelve cylinders is about one-ninth of the initial, first step pressure face.

19. The total pressure face area for all thirteen cylinders amounts to about one-sixth of the total initial pressure area used in step one. As a result, a pressure of more than 5,000 psi is concentrated on only small disconnected areas inside the bale.

20. In the fourth and final compression step, the remainder of the original compression face is moved downward.

In this step, the total compression force of 1300 metric tons is applied again. Due to the large size of the remaining pressure face, a pressure of only about 814 psi is finally applied to the refuse.

21. The fourth compression step of the main press completes the direct compression process of the Tezuka system. It does not, however, complete the production of the refuse bale.

22. The production of the bale is completed by the bale enclosure closing device which folds the enclosure used over the top of the bale.

23. The operating time of the Tezuka system is alleged to vary from about 10 to 15 minutes per 5-ton bale excluding any additional bale treatment.

24. The dimensions of the bale for the 1300 metric ton press are given at about 63 x 63 inches times variable height. The height variations indicated range from 37 to 70 inches.

25. It should be stressed that no indications are given that large refuse bales are made without an enclosure. It seems that the refuse is always compressed in the compression chamber lined with chicken wire or other materials.

A bale enclosure appears to be necessary because of the large bales and the in the over-all relatively low pressures applied in order to hold the bale together.

26. The Tezuka Kosan Company proposes various additional treatments for the already enclosed bale should this prove to be desirable.

Key additional treatment alternatives include

a) the encasement of the bale in concrete,
b) the dipping of the enclosed bale into asphalt,
c) the wrapping of the bale in vinyl or other materials, or
d) the strapping of the bale with metal bands or wires.

None of these additional bale treatments are needed if the refuse bales are disposed of through sanitary landfilling.

27. All Tezuka test and process performance data infer that municipal Tokyo refuse was used as an input material only. Bulky materials and other than normal municipal or residential refuse was apparently not compacted.

28. According to Tezuka the refuse used consisted by weight of approximately 40 percent paper, 25 percent kitchen garbage, 10 percent each of plastics, rags and cans plus bottles, and 5 percent wood.

The moisture content is given by Tezuka at approximately 60 percent by weight.

29. The claims made or implied for the characteristics of the bale are sometimes confusing and appear subject to doubt.

30. The physical stability of the large refuse bale itself is not known. Such large bales appear to need an enclosure to hold together.

31. The densities achieved are quoted to range from about 64 to 120 pounds per cubic foot. These large variations cannot be accounted for by the composition of the wastes as given.

The maximum density of compacted dry Tokyo refuse should not be much higher than 65 lbs/cu ft.

32. Only two to four percent of the moisture are stated as being released during compression. Thus the high density values might result mainly from the high moisture content. In terms of the Tezuka data, more than 50 percent of the weight of the bale could be accounted for by water.

Thus, in evaluating the system's performance it must be recognized that both variations in moisture content and in composition can lead to differences in the weight of the bales. United States refuse, as a rule, appears to be not as wet as that used by Tezuka Kosan.

Finally, it is not clear at this time whether the density measurements were adjusted to discount the weight of the enclosures used. The bale enclosures add only weight but do not increase the density of the refuse.

33. Tezuka claims that the waste liquid works like a binding material. The Japanese rice diet contains a significant amount of starch which is a good binder.

34. Tezuka alleges that moisture is removed during compaction by high temperatures. It is inconceivable that the process as presented could increase the temperature of the refuse appreciably.

35. It is most unlikely that the refuse bales are sterile as claimed.

36. The activity of aerobic bacteria in the bale is claimed to be almost zero. Yet, indications are given that partial aerobic degradation takes place. This indicates the availability of both moisture and oxygen.

37. It should be emphasized that fully enclosed, sealed and moist

bales could represent significant hazards. Anaerobic biodegradation could produce methane gas which might finally rupture the bale enclosure.

38. The volume reduction most commonly quoted in the Tezuka literature ranges from 5:1 to 7:1. In view of the density of the incoming Tokyo refuse, quoted at about 500 lbs/ cu yd, the latter volume reduction in particular appears to be high.

39. To produce a bale of the dimensions given and to economize in the application of pressures, the Tezuka system pays in production time and requires an elaborate process set-up.

40. It appears likely that smaller refuse bales of probably 3 x 3 x 3 feet dimensions can be produced without an application of the "Tezuka cylinder" compression approach.

41. The objective of producing large bales with a limited total pressure force appears to result in complicated machinery, complicated hydaulic switching arrangements and a large number of sequentially operating system elements.

42. The investment cost for the Tezuka system appear to be substantial if the building cost and transportation from Japan to Chicago are included.

43. The price for the equipment alone is given at $370,000 for a 150 ton/24 hour installation and at $7.1 million for a 3000 ton/ 24 hour installation.

44. Transportation from Yokohama to Chicago and import duty is estimated by Tezuka to cost from 25 to 30 percent of the equipment cost.

45. A 750 ton/24 hour installation requires about 720 square yards of space for the Tezuka equipment alone. The weight of the compression press is given at about 400 tons. Tezuka Kosan recommends that the building be ten times the size of the press area to accommodate associated process operations.

46. The operating cost for a 750 ton/24 hour installation have been calculated at $1.73 per ton.

47. These costs include $0.43 for the equipment depreciation calculated at a 25 year service life, $0.70 for labor, $0.10 for electrical energy, and $0.50 for chicken wire. The depreciation cost, of course, are higher for two or only one-shift operations.

48. These costs do not include maintenance expenditures, the depreciation for the building and foundations, and the depreciation and operating cost for any material handling or other equipment that might be needed additionally.

49. Other and additional bale enclosures such as sheet metal or concrete might increase the cost substantially.

50. At present the delivery time for the press is quoted at ten months. The assembly and erection time is quoted at an additional two months.

Conclusions

a) The main compression process uses an ingenious approach in utilizing a limited amount of pressure force by concentrating the force onto small areas.

b) This ingenious process also can produce zones of higher compaction inside the bale by applying compression forces below the original pressure contact surface.

c) By his approach Tezuka avoids expensive hydraulics needed to produce higher forces on the ram. If one assumes that the same results could be obtained without the cylinder approach by increasing the pressure to 3000 psi over the total pressure face, then the force on the ram would have to be increased by approximately 4.5 times.

d) The specific cost/performance values of the Tezuka process and its individual system elements can not be determined from the data presently available.

e) In the over-all the Tezuka system appears to be complicated and, in part, very cumbersome. As the size of the bale increases, the productivity of the press, in terms of tons of product per day per dollar of investment, will decrease rather than increase.

f) It is probable that the Tezuka process can be appreciably improved through additional process engineering.

The information as presented by the Tezuka Kosan Company is not conducive to a rigorous analysis and therefore a professional interpretation of the system. The information is incomplete and some of the data seem to relate to different processes. The confusion undoubtedly is caused, at least in part, by an inadequate translation.

III. THE TEZUKA REFUSE COMPRESSION SYSTEM ELEMENTS

The Tezuka Refuse Compression System consists basically of three major system building blocks and their associated subsystems. The three major elements are

1. The preliminary compression system,

2. The main compression system, and

3. Various equipment and coating methods to either reinforce or add cover material such as vinyl, asphalt or cement to the bales previously compressed, in almost all cases, in chicken wire mesh.

The third major element is not absolutely essential for a successful operation of the Tezuka Refuse Compression System. Rather it is intended to provide an additional cover for bales which are to be disposed of in various ways depending upon the plans of different Tezuka system users.

1. The Preliminary Compression System

Currently, Tezuka proposes two kinds of preliminary compression systems. The one involves a two or one stroke precompression approach. The other might employ up to two presses of which one operates with three strokes.

a) The two or one-stroke preliminary compression system

The two or one-stroke preliminary compression is accomplished by a horizontal ram and a cover door closed by hydraulic force.

The cover door is pulled down by two rams, one on each side, each exerting 50 metric tons of closing pressure. The

applicable size of the cover is approximately 1.6 x 4.68 meters or 62.99 x 184.25 inches or 5.24 x 15.35 feet. Thus the cover closing pressure is calculated at about 1.335 kg/cm^2 or 18.94 psi.

The horizontal ram exerts a force of 200 metric tons on a 1.6 x 0.8 meter or 62.99 x 31.49 inches pressure face. The pressures exerted on the refuse are 15.62 kg/cm^2 or 221.7 psi. The stroke of the ram is 5 meters or 16.4 feet.

The dimensions of the compression chamber are 1.6 x 0.8 x (about) 4.68 meters or 5.24 x 2.62 x 15.35 feet. The chamber is directly connected to one side of the main press. The bale is pushed by the horizontal ram through an hydraulically operated door into the main compression chamber by top loading.

b) A suggested two press preliminary compression system

In contrast to the two or one stroke preliminary compression system this version of the pre-compression equipment and approach has not yet been built and operated. The following description is based upon information as given by the Tezuka Kosan Company.

This second and alternative preliminary compression system consists of

i. a hydraulically operated "hopper for feeding" refuse, and
ii. a separate pre-compression device attached to the main press in the plans.

i. the "hopper for feeding" refuse

In this proposed installation three horizontal rams are set at a 90° angle to each other.

The center ram exerts a force of 300 metric tons on a pressure face of one square meter or 10.76 square feet. The pressures exerted on the refuse are 30 kg/cm^2 or 425.8 psi.

The two side rams exert a force of 200 metric tons each on a pressure face of 6 x 6 meters or 19.68 x 19.68 feet. The pressures exerted on the refuse are 0.555 kg/cm^2 or 7.87 psi.

The over-all dimensions of the "hopper" are 6 x 12 x 6 meters or 19.68 x 39.37 x 19.68 feet. The working capacity, however, is given at 300 cubic meters or 392 cubic yards. The hopper may or may not have a cover.

The two side rams do not work at all times. Their main function is that of moving the 19.6 x 19.6 feet side walls to accommodate varying volumetric densities of the incoming refuse.

The center ram pushes the refuse through an opening with the dimensions of 1 x 1 meters or 3.281 x 3.281 feet. There are also indications given that this opening might be larger than the pressure face dimensions of the ram which too are given at 1 x 1 meters or 3.281 x 3.281 feet.

According to Tezuka, a one cubic meter or 1.308 cubic yard bale made at this stage of the process and containing average Tokyo refuse weighs about 800 to 900 kg. This represents a specific gravity of 0.8 to 0.9 and a weight of 49.8 to 56.0 pounds per cubic foot.

The refuse at this point is not enclosed in chicken wire and the sides of the "bale" are uneven. Since the average Tokyo refuse, according to Tezuka, contains about 55 to 65 percent moisture by weight, the Tezuka Company expects that a considerable amount of liquid will be squeezed out at this stage of the total process.

The refuse, finally, is pushed by the center ram, sometimes also called "knock-out" ram, through a square, tapered metal pipe larger than 3.28 x 3.28 feet. The pipe, varying in length from maybe 15 to 30 feet, leads the refuse upwards at an angle of about 25 to 30 degrees into another hopper which then dumps it into the main compression chamber. The weight of the relatively wet refuse, moved upward, assists, of course, in the compression when the refuse exits through the opening indicated above.

The capacity of the second hopper is given as 10 cubic meters or about 13.0 cubic yards.

ii. the separate pre-compression device

The drawings and brochures of the Tezuka Kosan Company indicate an additional pre-compression device, hydraulically operated. This press is shown to additionally pre-compress the refuse when it is already in the main compression chamber. This pre-compression press is directly attached to the main press.

Any specifications of this second pre-compression press are not available at the present time.

To some degree both pre-compression systems perform functions equivalent to the gathering stroke on metal scrap balers. The total compression cycle time requires about one to one and one-half minutes in each of the two pre-compression approaches. The compression cycle time measures the time required by the rams to move to their forward point and to return to their point of origin.

2. The Main Compression System

The proposed main compression section of the Tezuka system also includes a number of variations. Some subsystems found in different proposals or descriptions appear to be the same, others appear to be optional. The following subsystems are identified in the Tezuka literature:

Standard elements

a) the main press,
b) a mobile compression chamber and bale enclosures,
c) a hydraulic compression chamber moving device,
d) a hydraulic device for closing and/or folding the bale enclosure on the top of the bale after compaction while the bale is still in the compression chamber, and
e) a hydraulic bale push-up device to remove the bale from the compression chamber;

Optional elements

f) additional mobile main compression chambers with the associated moving devices, and
g) a separate bale enclosure forming device consisting of a separate press and a mold similar in dimensions as the main compression chamber.

The Tezuka Main Compression system, of course, can operate without the optional system elements. The optional system elements are proposed for a speed-up of the process and the correlated increase in production.

If a separate bale enclosure forming device is not given, the first bale enclosure--in most cases chicken wire or thin metal sheet --is formed by the main press in the main compression chamber prior to the loading of the refuse. The refuse always is compressed within the first bale enclosure except in cases where pure scrap metal or materials with a similar compression behavior are handled exclusively. As in metal baling such materials hold together well and do not require an enclosure to provide stability for the bale.

a) The main press

The main press of the Tezuka system represents the genuine core of the Tezuka approach. Its design is said to be patented in various countries in the world.

The main ram operates vertically. The pressures exerted on the main ram currently are quoted at 1200 or 1300 or 1600 metric tons. The pressure face dimensions range from 165 x 165 to 180 x 180 centimeters or from 62.99 x 62.99 to 71 x 71 inches. The stroke of the ram in each case is three meters or 118 inches.

The following specifications are given for the 1300 metric tons main ram pressure design. Correlating data for the other two approaches are either not available, incomplete or not yet systematically worked out. Except for variations in dimensions, the basic approach, however, is similar in all three cases.

The main ram and its pressure faces are designed to perform four different compression operations successively:

i. In the first step, the total pressure of 1300 metric tons is applied to the total pressure face of 165 x 165 cm^2 or 62.99 x 62.99 inches. The pressure applied to the refuse amounts to 47.7 kg/cm^2 or about 675 psi.

   On the average the ram in this step moves downward from about 0.70 to 1.55 meters or about 27.5 to 61 inches.

ii. In the second step a solid cylinder is moved downward out of the center of the pressure face. The diameter of this cylinder is given at about 46 cm or 18.11 inches. Its maximum length is 50 cm or 19.68 inches.

   At this step a total force of 600 metric tons is applied. The cylinder has a pressure face of about 1660 cm^2 or 257.3 square inches. Thus a pressure of about 360 kg/cm^2 or 5120 psi may be exerted downward on the refuse.

   The pressure face area of this center cylinder is the equivalent of about one-sixteenth of the total pressure face area indicated for the first step. Thus the 5120 psi are applied to one-sixteenth of the top area of the bale.

   The volume displacement of the cylinder is about 5063 cubic inches. This is the equivalent of about one forty-seventh to one seventy-fifth of the total volume of the compressed refuse at this stage.

iii. In the third step twelve smaller solid cylinders are pushed downward either simultaneously or individually in a prearranged and/or variable pattern.

The twelve cylinders are all equal in size. Their diameter is about 17.5 cm or 6.88 inches and their maximum length again is 50 cm or 19.68 inches.

A total compression force of 1080 metric tons is applied to the twelve cylinders, 90 metric tons on each. With a total pressure area of 2904 cm^2 or 450.1 square inches, the force applied to the refuse amounts potentially to about 371.9 kg/cm^2 or 5278.6 psi.

The total pressure area of these twelve cylinders is the equivalent of about one-ninth of the original pressure face area indicated for the first step. It is the equivalent of about one-eighth if the pressure area of the center cylinder is deducted.

The total volume displacement of the twelve cylinders is about 8857.9 cubic inches. This is the equivalent of about one twenty-sixth to one forty-third of the total -- at this stage -- remaining volume of the compressed refuse, if the displacement of the fully extended center cylinder is deducted.

The combined pressure face area of all 13 cylinders amounts to about one-sixth of the initial pressure face area indicated in step one. The combined volume displacement of all 13 cylinders is about 13,920.0 cubic inches. This is the equivalent of one-seventeenth to one twenty-seventh of the total volume of the refuse as given after the completion of the first step.

iv. In the fourth and final compression step the remainder of the total original compression face is moved downward to level with the 13 cylinders pushed out in steps two and three.

Since the total pressure area of the 13 cylinders amounts to 4564 cm^2 or 707.42 square inches or only one-sixth of the original total compression area, the final compression face is about 22,661 cm^2 or 3512.4 square inches.

Now the total available compression force of 1300 metric tons is applied again in this phase. The pressures applied on the refuse thus amount to 57.36 kg/cm^2 or 814.14 psi. It should be highlighted that in this case the total compression force is applied to only the remainder of the original pressure face area, i.e. the initial pressure face minus the combined pressure area of the 13 cylinders.

The fourth step completes the main compression process in the Tezuka system. However, it does not yet complete the production of the bale except in cases when metal scrap or similar materials are compressed exclusively. The production of the bale is completed in an additional production step by the bale enclosure closing device. This device folds the chicken wire or sheet metal enclosure over the top of the bale.

The dimensions of the compressed refuse at the completion of the main compression process are 62.99 x 62.99 inches times variable height. The height variations of the bale are given in the Tezuka literature as ranging from 95 cm to 180 cm or 37.40 to 70.86 inches.

b) The mobile compression chamber

The main compression chamber of the Tezuka system is mobile. Its inside dimensions are about 165 x 165 x 300 cm or 62.99 x 62.99 x 118.11 inches. The capacity of the compression chamber is given at about 8.4 cubic meters or 10.98 cubic yards.

The main compression chamber is loaded in some system alternatives adjacent to the main compression press. After loading it is moved under the press for the compaction operations. If the pre-compression system is attached to the main press, the main compression chamber is, during loading, already in the position for the main compression. In both cases it subsequently is moved outside again for the bale to be pushed out.

c) The compression chamber moving device

The compression chamber moving device is capable of moving the chamber at a speed of 10 meters or 32.81 feet per minute.

d) The bale enclosure closing device

The bale enclosure -chicken wire or metal sheet- is placed into the main compression chamber before it is loaded with normal refuse. The bale enclosure device rolls and folds the upper part of the enclosure over the top of the bale after the compression has been completed.

It should be highlighted that in the Tezuka system normal refuse is always compressed within a chicken wire or sheet metal enclosure. Thus, the production

of the refuse bale is completed when the upper parts of the enclosure are folded over the top of the refuse bale. This is done while the bale is still in the main compression chamber.

e) Push-up device

The push-up device operate hydraulically with a force of 300 metric tons. The stroke length is 2.5 meters or 8.20 feet.

f and g) Optional system elements

Among the optional system elements only the separate bale enclosure forming device needs mentioning. The purpose, design and operations of the additional mobile main compression chambers are obvious.

The separate bale enclosure forming device is a horizontal press operating with a force of 50 metric tons. The mold for forming the chicken wire or sheet metal bale enclosure corresponds in dimensions to the dimensions of the main compression chamber.

3. Various Devices to Treat the Finished Bale

The Tezuka Kosan Company proposes various additional treatments of the already (usually in chicken wire) enclosed bale if this should be desired. The key additional treatment alternatives include

a) the enclosure of the bale in concrete by, as indicated in the Tezuka literature, a five step process;

b) the dipping of the bale into asphalt;

c) the wrapping of the bale in vinyl or other materials; and

d) the strapping of the bale with metal bands or wires.

Since these bale treatment operations are not essential for the refuse compression process, the equipment needed and/or proposed is not discussed here. The equipment needed for the additional treatment is well known and readily available.

The bale treatments indicated above are added to an already enclosed bale in order to increase the number of alternatives for a positive utilization of the refuse bales. Any additional bale treatment appears not to be needed if the refuse bale is disposed of through sanitary landfilling.

IV. THE OPERATIONS OF THE TEZUKA REFUSE COMPRESSION SYSTEM

The operations of the Tezuka Refuse Compression System require a number of distinctly separate process steps. The successive steps are as follows:

1. The first bale enclsoure consisting of chicken wire or sheet metal is formed either by the main compression press in the main compression chamber or in a separate bale enclosure forming device.

   If the first bale enclosure is formed in the separate bale enclosure forming device, the finished enclosure is subsequently placed into the main compression chamber.

2. The refuse is pre-compacted in either one of the two preliminary pre-compression operations.

3. The pre-compacted refuse is placed into the main compression chamber lined with the bale enclosure.

4. The pre-compression process in the two or one stroke preliminary compression system must be repeated four to six times in order to produce the load needed for the main compression chamber.

5. The main compression chamber is either already under the main press or moved into that position, if more than one chamber is used.

6. The main compression process takes place with the four separate steps as outlined in the description of the main press.

7. The bale enclosure is closed on top of the bale while the bale is still in the main compression chamber.

8. The main compression chamber is moved to the hydraulic push-up device.

9. The finished bale is pushed out of the main compression chamber.

10. The bale is moved, if desired, to the location of the subsequent bale treatment processes, i.e. coating with asphalt, reinforcing with a concrete shell, and strapping and/or wrapping.

The total operating time is quoted to vary from about 10 to 15 minutes per 5-ton bale excluding any additional treatment of the bale. The process capacity ratings are given on the basis of about 10 minutes process time for a 5-ton bale.

The compression time necessary to compact the refuse in the main press is given at 3-5 minutes. This includes the four compression steps and the time required for the ram to return to its original position.

V. RATIONALE OF THE TEZUKA REFUSE COMPACTION PROCESS

The compaction process rationale must be discussed in terms of the type of materials the process is applied to and the way in which a compact bale is produced.

1. The Composition of the Tokyo Refuse used by Tezuka

According to the Tezuka Company the composition of the average refuse as used in the test operations breaks down as follows:

Paper	approximately	40	percent	by	weight
Vinyl, plastic, etc.	"	10	"	"	"
Rags	"	10	"	"	"
Wood	"	5	"	"	"
Cans and Bottles	"	10	"	"	"
Kitchen garbage	"	25	"	"	"

The moisture content is estimated by Tezuka to amount to approximately 60 percent by weight in all cases.

With the exception of cans and bottles, most of the other solid items in the refuse have specific gravities of less than one. The specific gravity of wood can be as low as 0.2 and that of paper as low as 0.7. It would be expected, therefore, that the maximum density of compacted dry Tokyo refuse should not be much higher than 65 lbs/cu ft.

Wet compacted refuse, of course, could be much heavier since the specific gravity of water is 1.0. In view of the moisture content quoted, it must be expected that the weights per cubic foot as stated by Tezuka result largely from the relatively high water content.

In general, the high moisture content indicates that the refuse used by Tezuka must have been very wet. Tezuka implies that most

of the moisture is retained in the bale and that the moisture aids the compaction. Since the Japanese refuse contains an appreciable amount of starch from rice, the presence of moisture should facilitate the distribution of this binding material.

However, the large moisture content can also lead to difficulties, especially if the refuse contains a large portion of paper. The absorption of moisture by paper could result in a pulplike mass which behaves like mud under compression.

Finally, it should be stated that it is difficult to see that all the Tezuka test data refer, as claimed, to refuse of the composition and moisture content as indicated above.

2. Volume Reduction and Densities

To achieve a decrease in volume and thereby increase the density of the refuse, Tezuka introduces two compression stages: the pre-compaction and the main compaction.

The pre-compaction is carried out outside the main compression press and requires at least two steps in one approach and one step repeated four to six times in a second approach. The repetition of the pre-compression cycles in the second approach is needed in order to produce enough pre-compacted refuse to make up one load which fills the main compression chamber.

Four more compression steps are considered necessary by Tezuka to complete the compaction of the refuse by the main press.

These many compaction/volume reduction operations must be viewed in perspective to the density reached in the completed bale when dry. The volume reduction most commonly quoted in the Tezuka literature ranges from 5:1 to 7:1. The latter volume reduction in particular appears to be too high (if one

considers the high densities of the incoming refuse quoted to range from 500 pounds to 550 pounds per cubic yard.

The densities quoted by Tezuka for different bales range between about 64 to about 120 lbs/cu ft. These variations imply that the composition and/or the moisture content of the refuse differ appreciably from bale to bale. If the moisture content alone makes up 50 percent of the refuse weight in the bale, the actual density of the solid portion would amount to only about 32 to 60 lbs/cu ft. Furthermore, no mention is made whether the measurements were adjusted to discount the weight of the various bale enclosures and the weight of the moisture in the bales.

Finally, the many operations required in the Tezuka system result in a high cycle time of 10 to 15 minutes to produce one bale. To produce a bale of the dimensions given and to economize in the application of pressures, the Tezuka system pays in production time and perhaps an elaborate process set-up.

3. The Compaction Process in the Main Press

The compaction approach in the main press represents the unique core of the Tezuka system.

In the main press the compaction of the pre-compressed refuse is conducted, as described previously, in four stages.

In the first stage the refuse is further compressed by exerting a pressure of about 675 psi over the whole system area in contact with the ram. Due to the large surface area under compression, 3968 square inches, 675 psi is the maximum pressure achievable by the 1300 metric tons of force supplied. In turn, and at this stage, due to the relatively low pressure applied (675 psi), the large bale is most likely still full of voids. It should be recalled that the main compression chamber was initially filled with several loads of refuse pre-compacted with only 221 psi.

In order now to achieve a higher compaction without adding costly equipment, Tezuka utilizes the available force of 1300 metric tons by concentrating the force or parts of it onto smaller surface areas. This is accomplished by subdividing the ram into three sections each of which can be operated independently. As has been pointed out two of these sections used in steps two and three are made up of cylinders which can be moved out of the ram up to a distance of about 20 inches.

In the second step of compaction the center cylinder exerting a force of about 5120 psi moves into the bale. The additional compaction achieved by this step is not likely to be pronounced. The 5120 psi force is exerted only onto an area which is about one-sixteenth of the size of the initial compressed area. The volume reduction introduced by the displacement volume of the cylinder is only one forty-seventh to one seventy-fifth of the total volume of the refuse at this stage, i.e. prior to the extension of the center cylinder.

In the third step then the twelve cylinders move downward in a prearranged pattern. The force applied to the refuse is 5278 psi. The force is concentrated over an area about one-ninth of the initial main press compression area. The volume reduction achieved by the displacement volume of the cylinders is about one twenty-sixth to one forty-third of the refuse volume given prior to the extension of the twelve cylinders.

It should be stressed that the compressions in step two and three must be conducted separately. The main press has only 1300 metric tons of force available while step two requires 600 and step three, 1080 metric tons of force. Thus, while the compacting effectiveness of the second step alone appears to be very low, it gains importance when in combination with the third compaction. In this combination it helps to increase the total area under compression.

The third step consequently appears to be the most significant step of the Tezuka process. At this stage all 13 cylinders exert apparently a pressure of more than 5000 psi onto a surface area equivalent to approximately one-sixth of the initial compression area. A higher compaction in at least parts of the bale should result.

It could be visualized that as each cylinder moves into a dry bale it compresses the refuse at the contact area given. In a dry bale the compression force is transmitted primarily in the same direction as the movement of the cylinders. It is therefore also conceivable that the large area not under compression--and this area is about six times larger than the one now under compaction--is only slightly more compacted than the compaction achieved originally by the first step.

However, if the refuse is at least partially wet, or if other favorable conditions prevail, some of the wastes could be moved sideways with respect to the applied force. In this case additional compaction would result also in the areas not directly under compression by the 13 cylinders. In view of the high moisture content claimed for the bale it is possible that paper pulp is formed and partially squeezed into the non-compressed areas.

Nevertheless, it is most unlikely--if the waste does not behave like a mudlike material--that the compression forces, applied to one-sixth of the area, can be distributed evenly throughout the bale. As a result partial high compaction appears to occur directly below the surface of each cylinder creating zones of higher compacted material. The variations in the compaction probably explain why at the bale size given the compacted refuse has to be contained by an additional enclosure.

In the over-all an increase in the area of high compaction seems a fruitful approach. It is not quite clear why this has not been done to the maximum extent in step two. Tezuka utilizes only 600 metric tons of the 1300 metric tons available on the center ram leaving another 700 metric tons unused.

Furthermore, the contribution of the 13 cylinders to the compaction of the bale must be viewed in terms of the decreased distance between the cylinder head and the bottom of the bale. The cylinder movement of about 20 inches below the original surface decreases the distance through which the applied force has to be transmitted in order to compact the lower portion of the bale. This appears useful for cases in which large bales are to be prepared.

In the absence of specific data it is, however, difficult to determine whether both the traveling distance and the applied force of the cylinders are either necessary or adequate. If the counterforce of about 5000 psi of the compacted refuse is not reached at the distance of about 20 inches below the original surface, the cylinders will stop without being able to exert the full amount of the pressure force. If, on the other hand, the full counterforce is reached at a short distance below the surface the elaborate cylinder arrangement would seem unnecessary.

The fourth step in Tezuka's process consists of the downward movement of the remaining portion of the pressure face not occupied by the 13 cylinders. In this part of the operation the total 1300 metric tons of force available are applied again. Because the 13 cylinders occupy only a small area, this force application produces only an increase in pressure from 675 psi to 814 psi.

A flow diagram submitted by Tezuka suggests that the areas in between the cylinders are still filled with refuse before the

last portion of the ram is moved downward. This, in turn, would mean that the top portion of the refuse is only loosely compacted. It also means that the upper outside surface of the refuse bale exerts only a force of 814 psi onto the pressure face of the ram.

Finally the material to be compacted is initially placed inside a given container which is closed after the last compaction step. Since no data are given for bales formed without an enclosure, the stability of the compressed refuse "bale" is not known.

Nevertheless, it seems reasonable to assume that the Tokyo refuse materials as formed into relatively large bales by the Tezuka process do not adhere together well. Otherwise, it would be difficult to understand why a bale should always be enclosed, in most cases in chicken wire. Chicken wire exposes most of the bale surface; its only apparent function seems to be to confine the bale.

In terms of bale size and based upon previous work of the APWA rail-haul study team it appears likely that smaller refuse bales of probably 3 x 3 x 3 feet dimensions or less can be produced without an application of the "Tezuka cylinder" compression approach. The objective of producing large bales with a limited total pressure force appears to result in complicated machinery, complicated hydraulic switching arrangements and a large number of sequential process elements.

VI. SOME CLAIMS MADE OR IMPLIED FOR THE BALE

This section presents comments on some selected statements found in the Tezuka literature and not specifically discussed previously.

1. "The refuse reaches its yield point and loses its spring back force."

   The elimination of the spring back appears to be due to either the enclosure of the bale in chicken wire and/or the high moisture content. The 40 percent paper content represents the major spring back materials but paper that is wet does not provide for significant spring back.

2. "The majority of the waste liquid penetrates into the compacted refuse during compression and dries in a short period of time because of the temperature of the compacted refuse."

   It is difficult to see (a) how the necessary high temperatures can be produced in the bale by the relatively low overall pressures applied, and (b) how the moisture can diffuse out of the bale in a short period, if a well compacted bale has been formed.

   Particularly in cases in which the refuse is compacted inside a sheet metal container--closed immediately after compaction--it would appear that the moisture content of the baled refuse would be and remain appreciable.

3. "The waste liquid works like a binding material and helps to solidify the refuse."

   Japanese kitchen garbage contains a significant amount of starch because of the basic rice diet. Starch is a good binder. By comparison, American refuse contains little starch.

4. "Useful in a landfill because the land is filled with compacted and physically stabilized refuse."

   The terms "physically stabilized" could refer to the chemical binding provided by the starch waste liquid as well as the chicken wire or sheet metal enclosure.

5. "The specific gravity of the blocks of compacted refuse ranges from 1.05 to 1.8 which all sink in sea water."

   The specific gravity of water is 1.0. The specific gravity of the blocks in this case refers to refuse enclosed in sheet metal. By weight the sheet metal is quoted to amount from about 3 percent to 10 percent of the total bale. The thickness of the sheet metal is given to vary from 0.3 to 1.00 mm.

6. "Amazing compact refuse blocks" of specific gravity 1.05 to 1.8.

   "Refuse blocks" refer to compacted refuse enclosed in a variety of materials. According to Tezuka, the various bale enclosures are as follows:

   a) Chicken wire and hot asphalt
   b) Chicken wire and cement
   c) Chicken wire and vinyl
   d) Chicken wire or iron strap only
   e) Vinyl only
   f) Iron sheet, and
   g) no packaging material needed for the disposal of discarded automobiles, refrigerators, furniture, and iron scrap.

7. "The weight of the steel plate has a slight effect on the density."

The steel plate does not have any effect on the density of the refuse, it only adds weight. At best, the steel plate helps to maintain the density of the refuse by preventing the bale from disintegrating.

8. "The Tezuka press can compress loose garbage by 1/5 to 1/7 of its actual volume."

There are several compression steps used to reduce the volume of the refuse. A large reduction in the volume is already achieved before the refuse enters the main press. The volume reduction in the main compression appears to be in the neighborhood of two or perhaps two and one-half to one. The variations in volume reduction indicate that the solid to void ratio of the incoming refuse varies considerably from batch to batch.

9. "Iron Rocks"

The term "iron rock" refers to compacted refuse enclosed in sheet metal.

10. "Garbage turns to'Iron Rock;' the garbage rock arrives at its yielding point and changes into an iron rock, which permits free welding."

This implies a not quite proper use of the language and perhaps a slip-up in the translation.

11. "The garbage will solidify in bale form" - "The solidified bale."

Solidify is a relative term. The outside of the compacted refuse bale enclosed in chicken wire can be slightly indented with a finger without much pressure.

12. "Concrete-Iron Rock Process"

Refers to the enclosure of the refuse bale with concrete. This represents the second enclosure of the bale. The first enclosure applied with and during the main compression process consists in most cases of chicken wire or sheet metal. The concrete is poured around the bale which normally does not exist without the first enclosure.

13. "Concrete Blocks"

Refers to compacted and enclosed refuse additionally enclosed with a concrete shell. The concrete shell mainly appears to provide the weight carrying capabilities, if the blocks are to be used in the construction of buildings.

14. "In the press system, the exclusion of oxygen renders the refuse into a sterilized condition."

It is most unlikely that the compressed refuse is sterile. The absence of oxygen does not produce sterilization.

15. "It is easily imagined that CO_2 which is contained in the compacted and well dried refuse should be much lower than in the loose refuse."

Carbon dioxide (CO_2) is the end product of biochemical degradation of organic material. The decrease in CO_2 formation would indicate that the compacted refuse does not decompose as readily as loose refuse which must be expected.

16. "Technically, we have the understanding that the reactive velocity of bacteria becomes almost zero and quite negligible."

If the reactivity of bacteria is almost zero, the formation of CO_2 should also be almost zero.

17. "'Carbon dioxide,' CO_2, is drastically decreased and stablized as much as 1/3 after 300 days 'the gas concentration' is reduced to 20 percent by volume."

    The sentence is not quite clear, however, it implies that CO_2 is produced and therefore bacteria are active. The previous four statements indicate significant inconsistencies.

18. "Our ten years' experience and data show that aerobic bacteria are killed by denial of oxygen."

    Aerobic bacteria are not always killed by the denial of oxygen. The formation of CO_2 would indicate that nevertheless there is at least some aerobic activity.

19. "Further, anaerobic, together with facultative anaerobic bacteria lose their active propagation."

    This statement, as well as many other statements, are not documented.

The formulation of some of the above statements and claims suggest that the translator might not have been quite familiar with the subject matter. A poor translation easily can cause misinterpretations of the actual information the Tezuka Kosan Company desires to present.

VII. THE COST OF THE TEZUKA REFUSE COMPRESSION SYSTEM

The investment costs of the Tezuka Refuse Compression System appear to be quite high if the building and transportation costs are included.

The investment cost as shown in a Tezuka price list on the following page range from $370,000 for a 50 ton/8 hr installation to $7.1 million for a 1000 ton/8 hr installation for the equipment alone.

The transportation costs from Yokohama to Chicago via the St. Lawrence Seaway plus import duties are estimated by Tezuka to amount to 25 to 30 percent of the equipment cost.

A 250 ton/8 hr installation requires about 717 square yards of space for the main compression press plus the one or two stroke preliminary compression press directly attached to it. The weight of both presses is given at about 400 tons. The building, of course, must be larger than the press area to accommodate the associated operations. The Tezuka Company recommends making the building about ten times as large as the total press area.

The following calculations are made on the basis of a 250 ton/8 hr installation for which the most complete data are given by the Tezuka Kosan Company. The prototype system in the Tezuka plant is a 250 ton/8 hr refuse compression press.

	TIME OF OPERATION	
	8-hour	24-hour
Capacity	250 tons	750 tons
Equipment investment	$1.7 million	$1.7 million
Equipment investment per ton	$6,800	$2,266
Transportation cost 25%	$425,000	$425,000
Equipment and Transportation cost	$2.125 million	$2.125 million

Tezuka Refuse Processing Press Equipment
(Hydraulic-Concentrated pressure)

Disposal Capacity Per/8 Hours	Disposal Capacity In Three Shifts of 8 Hours	H.P.	Weignt of a Baled Refuse	F.O.B. Yokohama
50 Tons	150 Tons	Approx. 500	1 Tons	$ 370,000.
80 Tons	240 Tons	600	2 Tons	$ 530,000.
100 Tons	300 Tons	800	3 Tons	$ 730,000.
150 Tons	450 Tons	1,000	4 Tons	$ 1,090,000.
200 Tons	600 Tons	1,100	5 Tons	$ 1,400,000.
300 Tons	900 Tons	1,300	6 Tons	$ 1,940,000.
400 Tons	1 200 Tons	1,400	9 Tons	$ 2,500,000.
500 Tons	1,500 Tons	1,600	10 Tons	$ 3,330,000.
700 Tons	2,100 Tons	1,800	11 Tons	$ 4,610,000.
800 Tons	2,400 Tons	2,000	13 Tons	$ 5,550,000.
1,000 Tons	3,000 Tons	2,500	15 Tons	$ 7,160,000.

Simplified Refuse Processing Plant

Disposal Capacity, Per/8 Hours	H.P.	Weight of a Baled Refuse (kg)	F.O.B. Yokohama
10~15 Tons	100	100~200 kg	$ 166,800.
20~30 Tons	200	300~500 kg	$ 212,400.
40 Tons	300	600~800 kg	$ 250,200.

- Prices are subject to alteration without notice.
- The weight of baled refuse and horse power may be amended by manufacturer.

The above prices include :

1. Main packing press
2. Preliminary tightening press
3. Wire cage forming machine
4. Pumps & Motors
5. Asphalt Tank and Cooling Tank
6. Tezuka type activated sludge sewage equipment
7. Others as per our specifications

Remarks: Foundation, factory, building, crane guard, erection, transportation shall be in the account of buyer.
International Patent & Know-how royalty, U.S. $0.10 per weight ton of baled refuse shall be paid to the manufacturer during the operation period of the plant.

	TIME OF OPERATION	
	8-hour	24-hour
Equipment and Transportation cost per ton	$8,500	$2,833
Labor required per 8-hr shift	5	15
Cost of labor including fringe benefits @ 35 per 8-hr day	$175	$525
Labor cost per ton	$0.70	$0.70
Electricity	7-10 KW/ton	7-10 KW/ton
Cost of electricity at $0.012 per KW	$0.084 to $0.12/ton	$0.084 to $0.12/ton

The depreciation time for the press as given by the Tezuka Kosan Company is 20-30 years. Calculated on the basis of 25 years, the depreciation of the equipment and transportation cost amounts to $85,000 per year. Since the system theoretically is capable of handling 65,000 tons per year for a 260/8 hr working day, the depreciation costs amount to $1.30 per ton. If the system is run on 3-shift/260 working day per year basis, the tonnages processed increase to 195,000 and the depreciation decreases to $0.43 per ton.

Furthermore, cost for at least the chicken wire mesh are incurred since the five-ton bales are not made without at least such an enclosure. The total chicken wire mesh cost for a five-ton bale have been estiamted at $2.00 to $3.00 per bale or about $0.50 per ton.

Thus the cost per ton of refuse as identified above accumulate about as follows:

	ONE SHIFT OPERATION	THREE SHIFT OPERATION
Depreciation of equipment	$1.30	$0.43
Labor	0.70	0.70

	ONE SHIFT OPERATION	THREE SHIFT OPERATION
Energy	$0.10	$0.10
Chicken wire	0.50	0.50
	$2.60	$1.73

These costs do not include maintenance expenditures, the depreciation for the building plus the foundations, and the depreciation and operating cost for any material handling or other equipment that might be needed additionally.

Finally it should be stated that an enclosure of the bale in sheet metal or concrete or any other of the suggested materials does increase the cost substantially. The enclosure in sheet metal has been estimated to represent the most expensive bale enclosure costing anywhere from $25. to $50. per bale.

At present, the delivery time for the press is quoted at ten months. The assembly and erection time is quoted at an additional two months.

A P P E N D I X

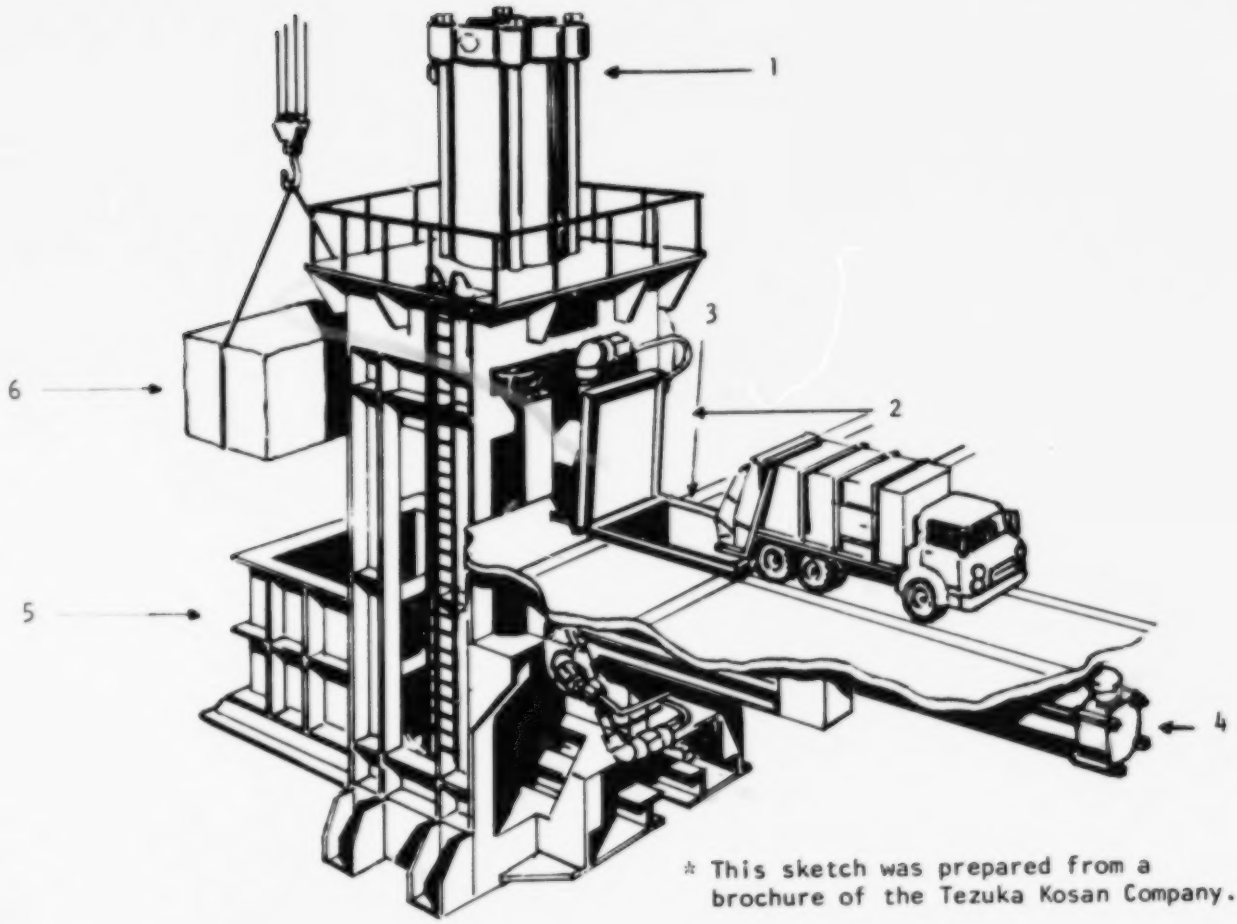
I. Sketch of the Full Scale
TEZUKA REFUSE COMPRESSION PRESS

II. The Operations of the Main Compression Ram
of the TEZUKA REFUSE COMPRESSION PRESS

III. Sketch of the TEZUKA REFUSE COMPRESSION PROCESS
utilizing more than one mobile main
compression chamber.

Sketch of the Full Scale

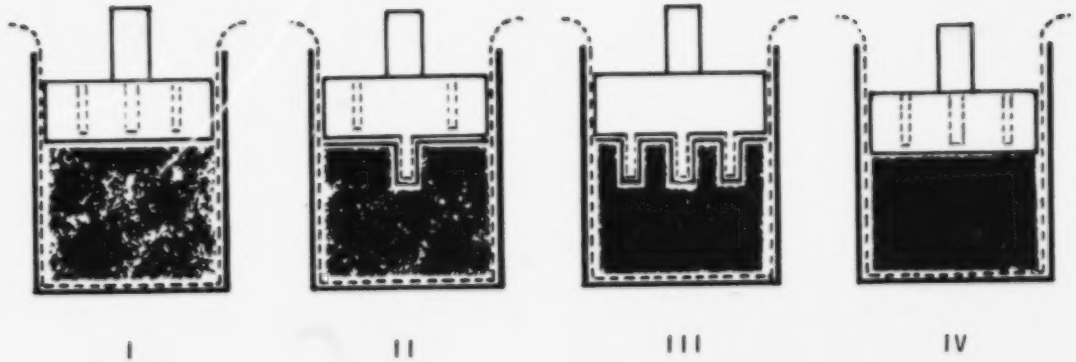
TEZUKA REFUSE COMPRESSION PRESS*



* This sketch was prepared from a brochure of the Tezuka Kosan Company.

1. Main Press.
2. Hydraulically operated door of the precompression chamber.
3. Precompression chamber.
4. Ram of the precompression chamber press.
5. Main compression chamber moved out from under the main compression press.
6. Finished, enclosed bale being removed from the compression chamber.

The Operations of the Main Compression Ram
of the Tezuka Refuse Compression Press



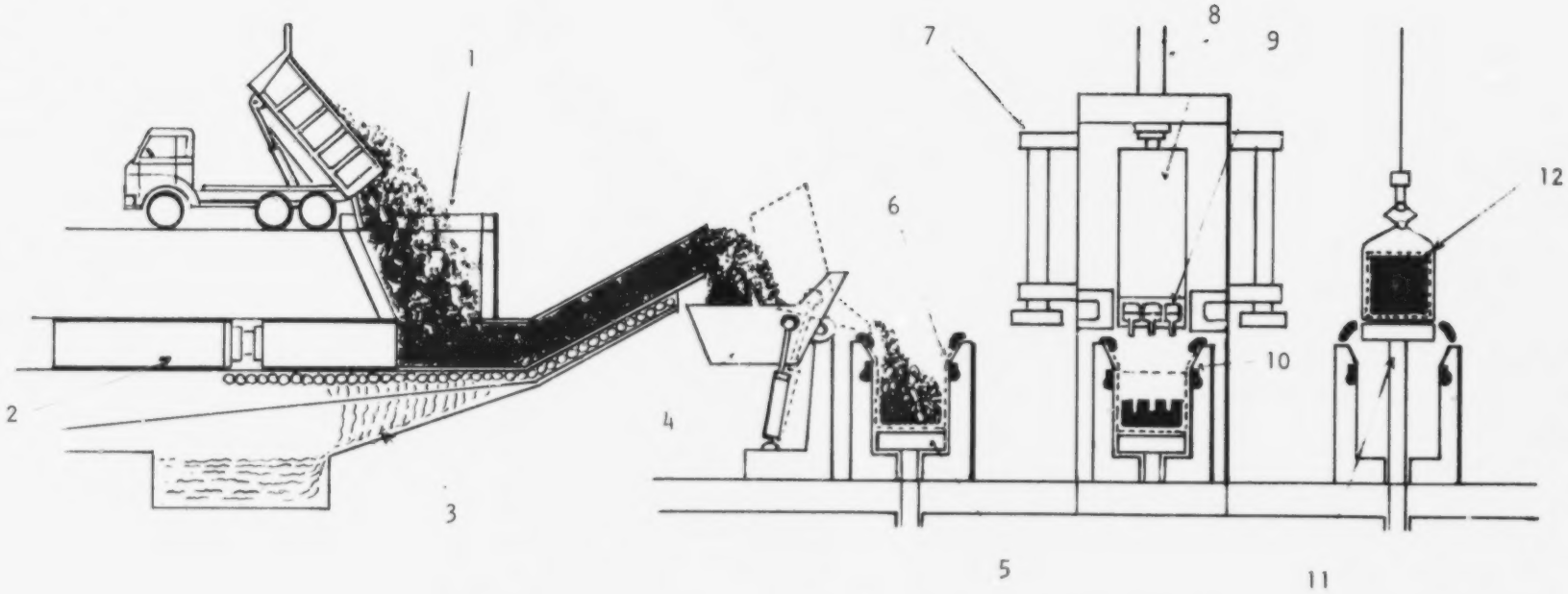
Step I. The main ram comes down until it exerts about 675 psi on the refuse in the main compression chamber. The main ram remains then in this position through steps two and three.

Step II. The center cylinder is pushed downwards. Its pressure face is about 1/16 of the total pressure face indicated in step one.

Step III. Twelve small cylinders are pushed downward. Each of these cylinders has a diameter of about 6.8 inches versus about the 18 inches diameter of the center cylinder. All cylinders are capable of exerting a pressure of about 5200 psi.

Step IV. The remainder of the original compression face is moved downward until it exerts a pressure of about 814 psi.

Sketch of the Tezuka Refuse Compression Process
utilizing more than one mobile main compression chamber.*



1. Hopper for feeding refuse.
2. Push-out cylinder.
3. Water/sewage runoff.
4. Hopper.
5. Mobile main compression chamber
6. Bale enclosure.
7. Pre-compression device.
8. Main compression press.
9. Movable cylinders in the main compression ram.
10. Bale enclosure folding device.
11. Push-up device to remove the enclosed bale from the main compression chamber.
12. Finished bale taken away by crane.

* This sketch was prepared from a brochure of the Tezuka Kosan Company.

U. S. GOVERNMENT PRINTING OFFICE: 1970 396-